

**Paper No. 03-2726**

**PRECAST PRESTRESSED CONCRETE PAVEMENT PILOT PROJECT NEAR  
GEORGETOWN, TEXAS**

*(Word Count: 4,127; 12 Tables & Figures)*

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**A paper offered for presentation and  
publication at the Annual Meeting of the  
Transportation Research Board.**

**Washington, D. C.**

**January, 2003**

## **ABSTRACT**

Precast concrete is rapidly becoming a viable method for repair and rehabilitation of portland cement concrete pavements, with several projects currently under construction or in development throughout the United States. Precast concrete offers numerous benefits over conventional cast-in-place pavement construction. Most notable is how quickly a precast pavement can be opened to traffic. Precast panels can be placed during overnight or weekend operations and opened to traffic almost immediately. And because precast panels are cast in a controlled environment, the durability of a precast pavement is also improved.

In March 2002, the Texas Department of Transportation (TxDOT) completed construction of a precast pavement pilot project aimed at testing and further developing a precast pavement concept developed by the Center for Transportation Research (CTR) at The University of Texas at Austin. This project was constructed on a section of frontage road along Interstate 35 near Georgetown, Texas. The project incorporated the use of post-tensioned precast concrete panels. The panels were post-tensioned in place to not only tie all of the panels together, but to reduce the required pavement thickness and improve durability. The finished pavement demonstrated not only the viability of precast pavement construction, but also the benefits of incorporating post-tensioning.

This paper will describe the details of the Georgetown precast pavement pilot project. Although the project was constructed without the time constraints and complexities that will eventually need to be considered for precast pavement construction, it ultimately helped to develop viable construction procedures for future precast prestressed concrete pavements.

## BACKGROUND

In response to an ever-increasing demand for methods to expedite roadway construction, the Center for Transportation Research (CTR) at The University of Texas at Austin completed a feasibility study, sponsored by the Federal Highway Administration (FHWA), which examined the use of precast concrete panels to expedite the construction of portland cement concrete pavements. From this feasibility study, a concept for precast pavement was developed which incorporated the use of prestressed precast panels. A final recommendation from the feasibility study was a staged implementation strategy for testing and refining the proposed concept. Staged implementation begins with small pilot projects to work out the casting and construction procedures on projects without stringent time constraints.

The first of these pilot projects was constructed by the Texas Department of Transportation (TxDOT) on a section of frontage road along northbound Interstate 35 near Georgetown, Texas. This project consisted of 0.7 km (2,300 ft) of precast pavement on either side of a new bridge. As recommended from the feasibility study, the project incorporated post-tensioning in order to reduce the required pavement thickness and to tie the precast panels together. The result was the development of viable precast pavement construction procedures that will allow for streamlined construction of future precast pavement projects.

## BENEFITS

The benefits of precast pavement are numerous; the most obvious being expedited construction. Using precast panels, construction can take place during overnight or weekend operations, allowing traffic onto the pavement almost immediately after placement. Extra time is not required for the concrete to reach sufficient strength before opening to traffic, as with conventional concrete pavement.

The economic benefit of expedited construction is realized through savings in user costs. User costs are the costs incurred by the users of the roadway due to the presence of construction activities, such as increased fuel consumption and lost work time. Although these costs are not easily quantified, they are costs that the motoring public can relate to.

Another major benefit of precast pavement is durability. Precast pavement panels are cast and cured in a controlled environment at a precast plant, allowing for much greater control in achieving a consistent concrete mix and ensuring that the panels are properly cured. This will minimize or even eliminate problems which are commonly encountered with conventional concrete paving, such as built-in curl/warp (due to temperature and moisture gradients), surface strength loss (due to insufficient curing), and inadequate air-entrainment.

Durability is also improved through post-tensioning. Post-tensioning not only reduces the required pavement thickness, but also greatly reduces or even prevents cracking from occurring. This not only increases the life of the pavement, but also results in significantly reduced maintenance costs.

## PRECAST PAVEMENT CONCEPT

The concept for the precast pavement constructed near Georgetown, Texas incorporates the use of full-depth prestressed precast panels. Previous experience with prestressed pavements has shown that prestress in both the longitudinal and transverse directions is essential (*1*). Therefore, transverse prestress is provided by pretensioning all of the precast panels during fabrication, and longitudinal prestress is incorporated by post-tensioning all of the panels together after placement.

The use of full-depth panels allows for opening to traffic immediately after panel placement is complete without the need for an additional operation to overlay the panels with a riding surface. Two key factors which must be considered when using full-depth panels are: 1) base preparation to provide a flat and level surface to support the panels, and 2) method for ensuring vertical alignment between adjacent panels so that initial ride quality is not compromised. With regard to base preparation, profile measurements obtained from a newly placed asphalt pavement during the feasibility study revealed that it is possible to place the precast panel directly over a thin (25 – 50 mm) asphalt leveling course (*2*). This is not only proved to be an economical solution, but an efficient solution in that the asphalt leveling course could be placed well in advance of the precast panels, allowing traffic onto the leveling course prior to panel placement.

Vertical alignment between adjacent panels is achieved by casting continuous shear keys into the edges of the panels to interlock the panels as they are set in place. Although shear keys along the panel edges required strict tolerances during casting, they allow the panels to be set in place rapidly without the need for additional measures to level-up adjacent panels.

A typical panel assembly for the precast pavement concept is shown in Figure 1. The panels are oriented with the longitudinal axis perpendicular to the flow of traffic. There are essentially three types of panels that make up a typical precast pavement slab: base panels, joint panels, and central stressing panels, shown individually in Figure 2. The panels are pretensioned in the transverse direction (long axis of the panel) during fabrication, and post-tensioning ducts are cast into each panel in the longitudinal direction for post-tensioning after all of the panels are in place. The “base panels” (Figure 2a) are essentially “filler” panels between the joint panels and central stressing panels. The number of base panels depends on the length of the finished post-tensioned slab (between expansion joints). The “joint panels” (Figure 2b) contain an armored expansion joint, similar to bridge a deck expansion joint, which absorbs the significant expansion and contraction movements of the finished post-tensioned slab. The joint panels also contain self-locking post-tensioning anchors for the post-tensioning strands which are fastened to either side of the armored expansion joint (Figure 2b).

Finally, the “central stressing panels” (Figure 2c) contain large pockets at every post-tensioning duct. The purpose of these pockets is to allow for post-tensioning to be completed from the center of the slab rather than at the post-tensioning anchorage in the joint panel. This allows for a continuous pavement placement operation, as access to the post-tensioning anchorage is not needed in order to complete stressing. The post-tensioning strands are fed into the ducts from the stressing pockets (Figure 7), threaded through all of the panels and inserted into self-locking anchors in the joint panels. The strands from each side of the stressing pockets are then coupled together and post-tensioned (Figure 8).

Following panel assembly and post-tensioning, the stressing pockets are filled with a fast-setting concrete or temporarily covered if time constraints do not permit filling the pockets. The post-tensioning strands are then grouted in the ducts. Grouting not only bonds the strands to the pavement so that individual panels can be easily cut out and replaced if necessary in the future, but more importantly, provides an extra layer of corrosion protection for the strands, which is particularly important at the joints between panels.

Corrosion protection for the strands is also provided by epoxy applied to the edges of the panels as they are assembled, similar to segmental bridge construction. Epoxy not only protects the strands from water infiltration, but also helps to seal the joints from grout leakage when the post-tensioning ducts are grouted. Epoxy further serves as a lubricant, allowing easier assembly of the panels, and also bonds the panels together so they will act like a continuous slab.

In certain cases it may not be possible to replace the entire pavement width, but rather one lane at a time. In this situation, it will be necessary to place two or more “partial-width” precast pavement slabs adjacent to each other and tie them together transversely. An additional post-tensioning duct cast into each panel in the transverse pavement direction, as shown in Figure 3, will permit adjacent slabs to be tied together transversely while ensuring load transfer across the longitudinal joint between slabs. Although only 1-2 transverse post-tensioning strands may be required, a flat (3 – 4 strand) transverse post-tensioning duct will permit slight misalignment of adjacent slabs.

One final aspect of the precast pavement concept is a single layer of polyethylene sheeting placed beneath the precast panels. The polyethylene sheeting serves as a friction reducing medium to minimize prestress losses in the pavement due to frictional resistance developed between the bottom of the panels and the leveling course. Previous research has shown a single layer of polyethylene sheeting to be a very effective and economical material for use as a friction reducing medium (3).

## GEORGETOWN PRECAST PAVEMENT

### Project Site

The Georgetown precast pavement pilot project was constructed on a section of frontage road of northbound Interstate 35. The project consisted of 700 m (2,300 ft) of precast pavement on either side of a new bridge, as shown in Figure 4. The site for this project was ideal for several reasons. First, the frontage road was closed to all but local traffic during construction. This allowed the project to be constructed without severe time constraints. Although the final application for precast pavements will be in urban areas, under extreme time constraints (overnight or during weekends), the purpose of this initial pilot project was simply to work out all of the

construction details of the precast pavement concept. Secondly, there are no horizontal curves and very gradual vertical curves along the section of frontage road. Although horizontal curves and superelevations are an issue that must eventually be addressed, a roadway with a simple geometric layout allowed for the basic construction procedures to be worked out first. Finally, the site for the Georgetown precast pavement was ideal because it will eventually experience heavy traffic, particularly truck traffic, as it will become part of an interchange for Interstate 35 and (proposed) State Highway 130. Heavy truck traffic will provide a good test of the long-term durability of the precast pavement concept.

The precast panels were oriented transverse to the flow of traffic, as shown in the panel assembly (Figure 1). This required panels which would span the full 11 m (36 ft) roadway width (two 3.7 m lanes, 2.4 m outside shoulder, and 1.2 m inside shoulder). To accomplish this, it was decided to use both full-width (11 m) and partial-width (5 m + 6 m) panels, in order to test the concept for partial-width panel construction. As mentioned previously, the partial-width (5 m and 6 m) panels were tied together through transverse post-tensioning. A standard slab length (between expansion joints) of 76 m (250 ft) was selected based upon estimated panel placement rate and anticipated slab movement. To meet the project limits, a longer slab length of 100 m (325 ft) for the partial-width panels, and a slightly shorter slab length of 68 m (225 ft) for the full-width panels were also incorporated. A standard panel width of 3 m (10 ft) was selected for all of the panels based upon fabrication (casting bed width) and transportation (weight limit) considerations. With this panel width, 26 precast panels were required for each of the standard 76 m slabs, including 22 Base Panels, 2 Central Stressing Panels, and 2 Joint Panels (half of each joint panel at each end of the slab).

### Thickness and Prestress Requirements

A pavement thickness of 200 mm (8 in) was chosen primarily on the basis of handling considerations. However, because this pavement is post-tensioned, it has an equivalent fatigue life, in terms of expected 80 kN (18-kip) ESAL (equivalent single axle load) applications to that of a 355 mm (14 in) continuously reinforced concrete pavement (CRCP). The compression that post-tensioning induces in the pavement allows for a greatly reduced pavement thickness as it minimized tensile stresses in the pavement. Although an equivalent 355 mm pavement is a much thicker pavement than needed for this frontage road, the purpose of this pilot project was to simulate what might be used on the main lanes of an Interstate pavement.

To achieve the 355 mm equivalent pavement thickness, a maximum prestress (at the ends of the slab) of approximately 1.45 MPa (210 psi) was required. This translated into 15 mm (0.6 in) diameter 1,860 Mpa (270 ksi) post-tensioning strands spaced at approximately 71 cm (28 in) across the width of the pavement (strands to be stressed to 80% of ultimate strength). However, for the purpose of standardization of strand spacing for future projects, a strand spacing of 61 cm (24 in) was selected, which further increased the effective thickness of the pavement.

Transverse pretensioning requirements were primarily governed by lifting stresses. A minimum prestress (from pretensioning) of 1.4 MPa (200 psi) was required to prevent cracking in the 11 m long panels when lifted approximately at the quarter-points.

### Panel Fabrication

The panels were cast on a "long line" casting bed 122 m (400 ft) in length. Long line casting allowed for ten full-width (11 m) panels, and up to 20 partial-width panels to be cast at one time, end to end (Figure 5). The pretensioning strands extended continuously the full length of the casting bed passing through all of the panels. After release of prestress, the pretensioning strands between each of the panels were cut and the panels were removed from the forms. Long line casting did require special attention to the side forms to make sure there were no imperfections or misalignment that might prevent the keyed panel edges from matching up. In total, 123 full-width (11 m) panels and 216 partial-width (5 m and 6 m) panels were cast.

The mix design used for the pavement panels was a mix similar to that used for precast prestressed bridge beams. The mix used Type III cement with a water-cement ratio of 0.42 and superplasticizer for increased workability. A mix of this nature, which is not typically used for pavements, was necessary to develop sufficient strength for release of prestress and removal from the forms the following day. The specifications for the precast panels required that the concrete reach a minimum compressive strength of 24.1 MPa (3,500 psi) at release of prestress, and a 28-day compressive strength of 34.5 Mpa (5,000 psi). The mix was also required to be fluid enough during casting that a carpet drag finish could be applied at sheen loss. The use of an intermediate curing

compound, similar to monomolecular film, was also required to minimize water loss during casting, followed by two applications of curing compound after the surface texture was applied.

### Panel Assembly

After enough panels were cast, panel assembly began over the asphalt leveling course (Figure 6). The panels were delivered to the site one panel per truck (three panels per truck for partial-width panels), and placed one section (between joint panels) at a time. As each truck was waiting to unload, a slow-setting segmental bridge epoxy was applied to the panel edges. The epoxy not only aided with assembly of the panels by acting as a lubricant, but also helped to seal the joints between panels to protect the post-tensioning strands and prevent grout leakage.

A single layer of polyethylene sheeting (friction reducing medium) was rolled out prior to the placement of each panel. A 578 kN (65 ton) capacity crane was then used to lift each panel off of the truck and set it in place. During placement of the first few sections, approximately 25 full-width (11 m) panels could be placed over an 8-hour period. This placement rate varied depending on the number of workers available. Towards the end of the project, 25 panels could be placed in approximately 6 hours.

Once all of the panels had been set in place, the post-tensioning strands were fed into the ducts at the central stressing pockets and fed through the panels in both directions to the self-locking anchors in the joint panels. After all strands were coupled in the stressing pockets, each tendon was stressed with a monostrand post-tensioning ram to 80% of the ultimate strength of the strand, as specified in the design plans (Figures 7, 8).

Placement of the partial-width panels was completed slightly faster than the full-width panels. One section of 6 m (20 ft) panels were set in place and post-tensioned, followed by the adjacent section of 5 m (16 ft) panels (Figure 9). After each set of partial-width panels were in place, the transverse post-tensioning strands were fed through the panels. The longitudinal tendons were then stressed, followed by the transverse tendons.

All post-tensioning was completed within 24-48 hours after placement of the panels, while the epoxy was still pliable, to ensure the transverse and longitudinal joints between panels were pulled closed as much as possible. After stressing was complete, the stressing pockets were filled and the post-tensioning strands were grouted in the ducts.

### Ride Quality

Following construction, a high-speed inertial profilometer was used to evaluate the ride quality of the finished pavement. One pass was made in each of the lanes over the length of the pavement. Table 1 shows the results from the pavement smoothness measurements. The average International Roughness Index (IRI) was 2.61 m/km (165.5 in/mile) for the partial-width panels and 2.32 m/km (147.1 in/mile) for the full-width panels. Although these values are higher than that which would normally require correction for conventional concrete pavement, TxDOT felt that the ride quality did not warrant diamond grinding or any other corrective measure (Figures 10, 11). A more detailed analysis of the profile data should provide insight into specific causes of higher roughness indices. No irregularities, which could lead to dynamic loading and premature pavement failure, were observed in any of the panels. For future applications, a ride quality standard should be established for precast pavement that will determine whether the finished pavement is smooth enough for immediate traffic use. Smoothness incentives and penalties would help to ensure a high quality finished product from the contractor.

### COST COMPARISON

As stated at the beginning of this paper, the biggest benefit of precast pavement is expedited construction. Precast panels can be set in place quickly and the pavement can be opened to traffic almost immediately. This will allow for construction to take place during overnight and weekend operations, when traffic volumes are low. Construction during off-peak hours will result in a significant reduction in user delays caused by pavement construction using conventional paving methods. This reduction in user delays translates into a significant savings in user costs.

With the implications of user costs in mind, construction costs should be evaluated accordingly. The total cost of the Georgetown precast pavement, including panel fabrication, base preparation, and construction, was approximately \$203/m<sup>2</sup> (\$170/yd<sup>2</sup>). Although this cost is significantly higher than what might be expected for an equivalent 355 mm CRCP (\$36 - \$48/m<sup>2</sup>), there are several factors which greatly contribute to this higher cost.

First, the Georgetown precast pavement was a relatively small (0.7 km) project, and as with any construction project, there are economies of scale. A much larger project would have had a significantly lower unit cost. Secondly, the Georgetown precast pavement project was experimental in nature. Neither the contractor nor the precast supplier were familiar with precast paving techniques and therefore likely submitted higher bids. It is important to remember that, as with any new construction method (such as the first continuously reinforced concrete pavement), the initial costs will be higher until contractors and transportation agencies become familiar with the techniques.

## CONCLUSIONS

The precast pavement pilot project near Georgetown, Texas is only the beginning for precast pavement construction. While this first pilot project did not include all of the intricacies anticipated in future precast pavement projects, it did demonstrate the viability of basic precast paving techniques. It demonstrated that not only can precast panels be used effectively for pavement construction, but that post-tensioning can also be incorporated.

The economic benefit of precast pavement will be realized through substantial savings in user delay costs. Although the initial construction costs may be higher than that of conventional concrete pavement, the savings in user costs should make precast pavement appealing to transportation agencies as well as the motoring public. Other benefits of precast pavement include reduced pavement thickness, which is beneficial for construction in areas with limited overhead clearance, and increased durability. The high degree of quality control afforded at a precast plant, and the benefits of post-tensioning, will ensure excellent long-term performance of precast pavement.

The Georgetown pilot project presented many challenges for precast pavement implementation. Perhaps the most difficult aspect was meshing precast concrete and concrete pavement specifications. This required flexibility on the part of both the precast supplier and TxDOT. This project also represented unknown territory for the contractor, precast supplier, and TxDOT. Flexibility and a willingness to develop new techniques on the part of all parties were essential.

The success of this pilot project in developing streamlined fabrication and construction procedures will eventually lead to applications on projects with much more stringent construction time constraints. Ultimately, it is hoped that precast pavement will be used where it is needed most, on urban freeways, urban intersections, and airport runways and taxiways, where construction must have virtually no impact on traffic. This is where the true benefits of precast pavement construction will be realized.

## ACKNOWLEDGMENTS

This paper represents part of an implementation study sponsored by the Federal Highway Administration and the Texas Department of Transportation. The following project directors and other individuals involved with the Georgetown pilot project are acknowledged for their assistance in the successful completion of this project: Mark Swanlund (FHWA), Suneel Vanikar (FHWA), Steve Forster (FHWA), William Garbade (TxDOT Austin District), TxDOT Georgetown Area Office, TxDOT Bridge Division, TxDOT Materials and Test, TxDOT Pavement Design, TxDOT Victoria Field Office, Granite Construction Company, Texas Concrete Company, and Dywidag Systems Int'l.

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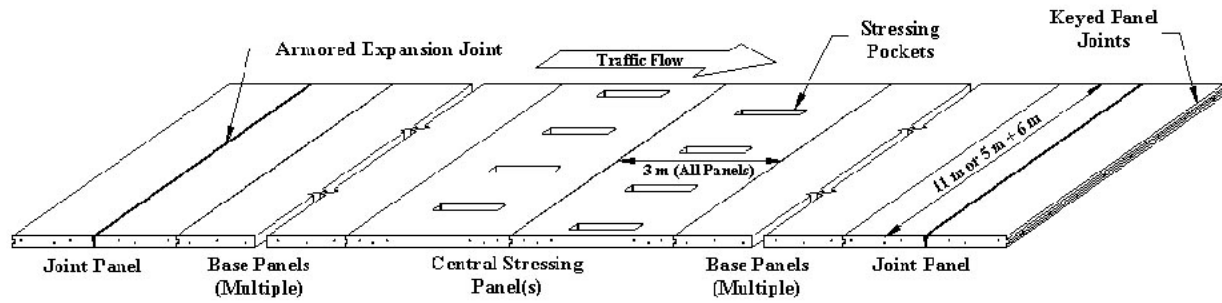
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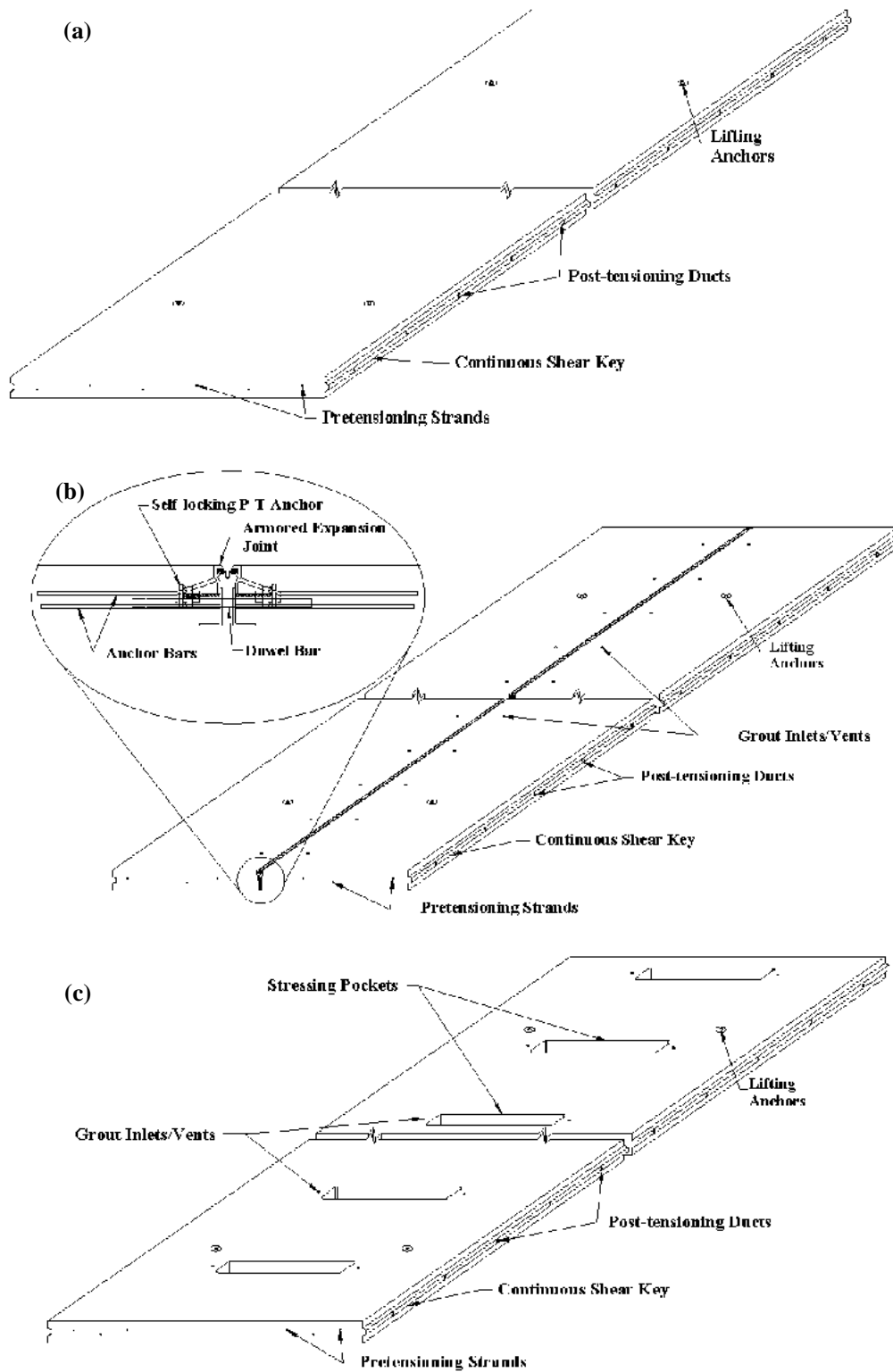
**TABLE 1 Pavement smoothness measurements using a high-speed inertial profilometer for partial-width and full-width panels.**

	Partial Width Panels				Full-Width Panels			
	<i>Inside Lane</i>		<i>Outside Lane</i>		<i>Inside Lane</i>		<i>Outside Lane</i>	
	<b>LWP</b>	<b>RWP</b>	<b>LWP</b>	<b>RWP</b>	<b>LWP</b>	<b>RWP</b>	<b>LWP</b>	<b>RWP</b>
<b>IRI m/km (in/mi)</b>	2.68 (170.0)	2.67 (168.9)	2.58 (163.6)	2.52 (159.6)	2.50 (158.6)	2.41 (152.5)	2.14 (135.5)	2.24 (141.7)

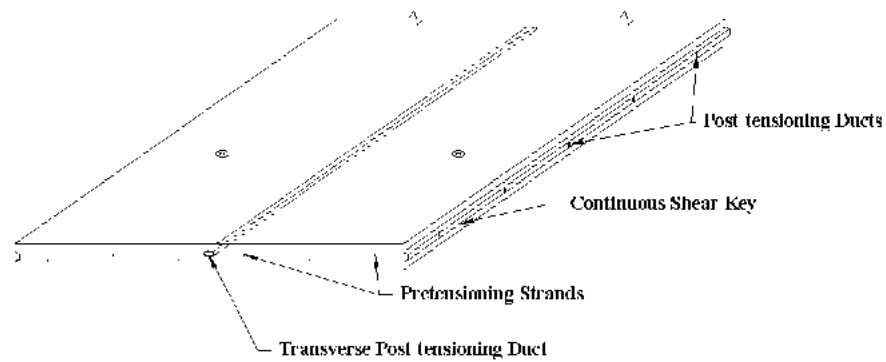
**LWP** = *Left Wheel Path*, **RWP** = *Right Wheel Path*



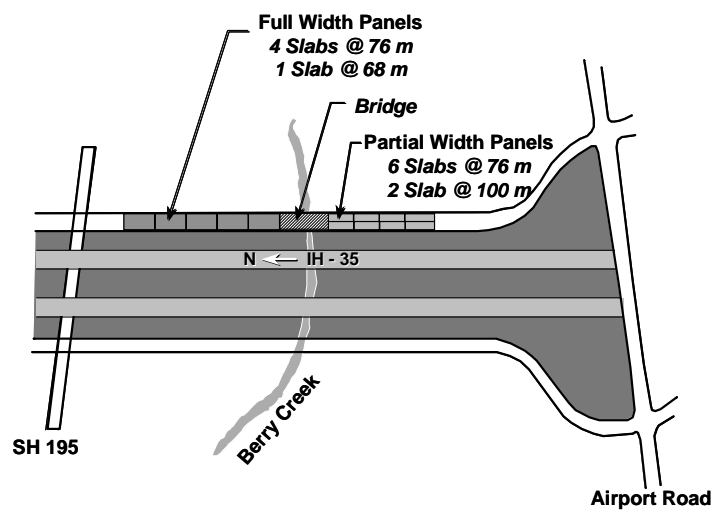
**FIGURE 1** A typical panel assembly showing the three types of precast panels that make up a finished slab. Dimensions shown are that used for the Georgetown Pilot Project.



**FIGURE 2** Three types of panels used for the Georgetown precast pavement: (a) Base Panel, (b) Joint Panel, (c) Central Stressing Panel.



**FIGURE 3** Typical “partial-width” base panel with additional transverse post-tensioning duct.



**FIGURE 4** Location and layout of the Georgetown precast pavement pilot project. Note: each “slab” represents a post-tensioned section of precast panels, including base panels, joint panels, and central stressing panels.



**FIGURE 5** Finished set of full-width base panels in the casting bed.



**FIGURE 6** Placement of a full-width base panel over the asphalt leveling course.



**FIGURE 7** Post-tensioning strands are fed into the ducts at the central stressing pockets in both directions.



**FIGURE 8** The post-tensioning strands from each end of the slab are coupled together and tensioned in the central stressing pockets.



**FIGURE 9** Placement of a 5 m “partial-width” base panel, over polyethylene sheeting, adjacent to a 6 m slab already in place.



**FIGURE 10** Typical transverse joint between panels. Keyways along the edges of the panels helped to ensure vertical alignment between panels.



**FIGURE 11** A view of the finished pilot project after being opened to traffic.